ENGINEERING DISPERSION TO INCREASE THE BANDWIDTH OF AN EFFICIENT METAMATERIAL-BASED ELECTRICALLY SMALL ANTENNA

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An electrically small dipole antenna is known to be a very inefficient radiator, i.e., because it has a very small radiation resistance while simultaneously having a very large capacitive reactance, a large impedance mismatch to any realistic power source exists. It has been demonstrated recently, for instance in [R. W. Ziolkowski and A. Erentok, "Metamaterial-based efficient electrically small antennas," submitted to IEEE Trans. Antennas Propagat., June 2005] and in [R. W. Ziolkowski and A. Erentok, "At and beyond the Chu limit: passive and active broad bandwidth metamaterial-based efficient electrically small antennas," submitted to IEE Proceeding, December 2005], that enclosing an electrically small dipole antenna in an electrically small epsilon-negative (ENG) shell leads to an efficient electrically small radiator. The inductive nature of the ENG shell compensates for the capacitive nature of the electrically small dipole antenna functioning as a distributed matching element that forms this "geometrically" resonant system. More realistic electrically small center-fed electric dipole-ENG spherical shell and coax-fed electric monopole-ENG hemispherical shell antenna systems have also been modeled numerically using ANSOFT's High Frequency Structure Simulator (HFSS). The input resistance and reactance of these realistic antenna-ENG shell systems were obtained from these numerical models. It has been shown that these systems could be designed to have geometrical resonances for which the relative gains were analogous to the radiated power ratios obtained with the analytical models. With further tuning, it has also been shown that an "antenna" resonance, where the system has a zero input reactance and an input resistance that is matched to a specified source resistance, can also be realized to yield a very high overall efficiency. These systems were evaluated assuming ideal (dispersionless) ENG material properties; they were shown to be efficient and to have bandwidths substantially beyond the value predicted by the Chu limit without any degradation in the far-field radiation patterns of the constituent antenna. The presence of dispersion causes these bandwidths to narrow considerably to values very near to the Chu limit. With dispersion engineering, large bandwidths can again be obtained.

The canonical problem of a radiating infinitesimal electric dipole antenna that is centered in a multi-layered, concentric metamaterial-based spherical shell system has been solved. Resonant systems based on a glass enclosed ENG gain layer, the gain layer being realized with two types of engineered, active doublet dispersion models, are considered. Both Lorentz-Lorentz and 2TDLM-Lorentz gain doublet dispersion models are considered. Typical results for the dispersionless and dispersion engineered systems will be given in our presentation. It will be demonstrated that both of these systems have fractional bandwidths that approach the idealized dispersionless value and, consequently, are significantly beyond the Chu limit.